

3/PATS

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ELECTROCHEMICAL SENSOR

## Background Information

The present invention is based on an electrochemical sensor according to the definition of the species in Patent Claim 1.

The sensors of this species must be heated in the active range to temperatures of more than ca. 350°C to achieve the necessary ionic conductivity of the solid electrolyte body. To increase the measuring accuracy of the sensor, it is known to control and, if necessary, to adjust the operating temperature of the measuring cell, i.e., of the solid electrolyte body in the measuring region. To this end, it is known to assign a heating device to the sensor, the heating device being capable of being switched on and off as a function of an operating temperature measured at the measuring cell.

To determine the operating temperature of the measuring cell, it is known to apply an a.c. voltage to the sensor and to use a measuring device to determine a total alternating-current resistance made up of the conjugate impedances of the solid electrolyte body and of the corresponding electrodes and electrode leads. The temperature-dependent internal resistance of the solid electrolyte body in the measuring region and, as such, its temperature in the measuring region can be deduced from the total resistance.

In the known method, it is disadvantageous that the measuring device, which determines the temperature-dependent resistance of the solid electrolyte body, uses a constant resistance of the electrodes and the electrode leads as a baseline. However, the resistance of the electrode leads and the electrodes is subject to a relatively high degree of scatter due to manufacture.

The measuring device adds this not insignificant scatter error to a temperature-dependent change in the resistance of the solid electrolyte body in the measuring region and provides a corresponding faulty control signal for the heating device of the sensor. As a result, the sensor

is adjusted to an incorrect operating temperature.

It is further disadvantageous that, in the lead region, the solid electrolyte body forms an additional internal resistance that is connected in parallel to the internal resistance of the solid electrolyte body in the region of the electrodes (measuring region) and also makes a not insignificant contribution to the total resistance. If, in addition, the temperature in the lead region is higher than in the measuring region, the internal resistance of the solid electrolyte body in the lead region is reduced, and it makes a contribution to the total resistance that is dependent on the temperature of the solid electrolyte body in the lead region. As a result, the sensor is likewise adjusted to an incorrect operating temperature.

To avoid the effect of the internal resistance in the lead region, it is known from DE 198 37 607 A1 to provide the lead of an electrode opposite the lead region of the solid electrolyte body with an electrically insulating layer. This design has the disadvantage that the use of at least one insulating layer additionally requires at least one printing step and is, therefore, expensive from a standpoint of production engineering.

### Summary of the Invention

In comparison with the related art, the electrochemical sensor according to the present invention and having the characterizing features of the independent claims has the advantage of an improved regulation of the operating temperature, thereby enabling the sensor to function more precisely and more uniformly.

The invention described by the characterizing features of Claim 1 achieves that the internal resistance between the electrode leads situated on a solid electrolyte body is significantly higher than that between the electrodes in question. Thus, the contribution to the total resistance made by the internal resistance in the lead region of the solid electrolyte body, which is connected in parallel to the internal resistance in the measuring region of the solid electrolyte body, is significantly reduced. Thus, the influence of the internal resistance in the lead region on the temperature regulation is negligible. An additional advantage from a standpoint of production engineering is that by dispensing with an electrically insulating layer, a printing step is no longer necessary.

According to the invention described by the characterizing features of independent Claim 11, the resistance of at least one electrode lead makes a small contribution to the total resistance. Furthermore, the electrode lead is made of a material having a smaller degree of processing scatter with respect to its resistance. Thus, the effect of the resistance of the electrode lead on the total resistance is smaller.

The invention according to independent Claim 21, which represents a combination of the distinguishing features of the first and the second independent claims, additionally improves the regulation of the operating temperature of the sensor.

The measures set forth in the dependent claims make possible advantageous developments of the sensor recited in the independent claims.

Designing the internal pump electrode lead and/or the reference electrode lead using a material having a lesser ionic conductivity or no ionic conductivity in comparison with the electrode in question has the additional advantage that the resistive coupling of the particular electrode leads that can lead to a loading effect of the pump voltage on the measuring voltage of the sensor cell is prevented. As a result, the  $\lambda=1$ -ripple is decreased or even prevented, thereby further improving the control dynamic response of the sensor.

An additional advantage results from designing the external pump electrode lead and/or the internal pump electrode lead using a material having a low resistance in comparison with the material of the electrode in question. As a result, the drop in the pump voltage in the external pump electrode lead and/or internal pump electrode is reduced, thereby improving pump function.

A particular embodiment of the present invention provides that the reference electrode lead is situated in the layer plane of the heater, thereby eliminating at least one printing step. In a further embodiment of the present invention, the heater and reference electrode lead are produced from the same material, thereby resulting in an additional advantage from a standpoint of production engineering.

Brief Description of the Drawing

The present invention is explained in greater detail by the drawings and the subsequent description. The figures show:

- Figure 1 shows an exploded view of a first exemplary embodiment of a sensor;  
Figure 2 shows an exploded view of an additional exemplary embodiment of a sensor;  
Figure 3 shows a top view of an electrode including an electrode lead of a sensor; and  
Figure 4 shows a top view of an electrode including an electrode lead as well as a heater.

## Description of the Exemplary Embodiments

Figure 1 shows an electrochemical sensor for analyzing gases, in the form of a planar sensor element 10. Sensor element 10 including a measuring region 61 and a lead region 62 has electrical connection contacts 60, a first solid electrolyte foil 11 designated as a heating foil, an insulating layer 12, a heater 13, an additional insulating layer 14, a second solid electrolyte foil 20 designated as a reference gas duct foil, as well as a reference electrode 21 having a reference electrode lead 22. Formed in reference gas duct foil 20 is a reference gas duct 29, which is connected via an opening in the lead region to air as a reference gaseous atmosphere. Above reference electrode 21 and reference electrode lead 22, the sensor element further has a third solid electrolyte foil 23 designated as a measuring foil, a measuring electrode 26 including measuring electrode lead 27, as well as a porous protective layer 28.

Figure 2 shows an additional exemplary embodiment of an electrochemical sensor for analyzing gases. This sensor is a so-called broadband probe having two cells 37, 38. First cell 37 is a concentration cell that functions according to the Nernst principle. The operating mode of first cell 37 corresponds with the sensor described in Figure 1. Therefore, the same reference numerals are used for the same elements in Figure 2. Second cell 38 is an electrochemical pump cell that is laminated together with first cell 37 and that cooperates with the concentration cell in a method known per se, according to the functional principle of the broadband probe. Situated in the junction region between first cell 37 and second cell 38 is an intermediate layer 35 and a filler layer 34 for forming a space (not further represented) for accommodating diffusion barrier 30. Second cell 38 has an internal pump electrode 31, including an internal pump electrode lead 32, a fourth solid electrolyte foil 33 designated as a

pump foil, an external pump electrode 40, including an external pump electrode lead 41, and a porous protective layer 42. Measuring electrode lead 27 and internal pump electrode lead 32 run together in lead region 62 of sensor element 10.

5 Figure 3 shows a large surface of a solid electrolyte foil 49 having an electrode 50 and an electrode lead 51, which can, for example, form measuring electrode 26, including measuring electrode lead 27, or reference electrode 21, including reference electrode lead 22, of the sensor shown in Figure 1. The electrode 50 shown in Figure 3, including electrode lead 51, can, for example, also represent external pump electrode 40, including external pump  
10 electrode lead 41, internal pump electrode 31, including internal pump electrode lead 32, measuring electrode 26, including measuring electrode lead 27, or reference electrode 21, including reference electrode lead 22, of the sensor shown in Figure 2.

Electrode lead 51 is made of an electrically conductive material, preferably platinum, and has a ceramic component for mechanical stabilization of 7% by volume  $\text{Al}_2\text{O}_3$ , for example. Electrode 50 is made of a catalytic material, preferably platinum, and a ceramic material, preferably 20% by volume  $\text{ZrO}_2$  stabilized with  $\text{Y}_2\text{O}_3$ . In an additional embodiment, electrode 50 further has a porosity produced by a pore-forming material. The junction  
20 between electrode 50 and electrode lead 51 is produced by a wedge-shaped junction region 52 having an overlap zone. Electrode 50 and electrode lead 51 are produced according to a method known per se, e.g. by screen printing.

The described design can be used in any combination for every electrode shown in Figures 1 and 2 and for the respective electrode leads. It is conceivable to also use the described design  
25 of electrode 50 including electrode lead 51 for other electrochemical sensors of this type.

In the exemplary embodiment for the broadband probe (Figure 2), internal pump electrode lead 32 and/or reference electrode lead 22 are produced using  $\text{Al}_2\text{O}_3$  as the ceramic component to reduce the  $\lambda=1$ -ripple. In comparison with the  $\text{ZrO}_2$  stabilized with  $\text{Y}_2\text{O}_3$ ,  
30 which is suitable as the ceramic material for electrode 21, 31, the  $\text{Al}_2\text{O}_3$  possesses no ionic conductivity. As a result, there is no ionic conduction between electrode leads 22, 32, thereby increasing the internal resistance in this region.

A further exemplary embodiment of a broadband probe (Figure 2) is that to reduce the drop in pump voltage in the lead region, external pump electrode lead 41 features a material having a low resistance in comparison with the material of external pump electrode 40. This is achieved in that the proportion of electrically conductive material, e.g. platinum, is higher in the cermet material of external pump electrode lead 41 than in external pump electrode 40.

Figure 4 represents an additional specific embodiment in which electrode 50 and electrode lead 51, including a junction region 52, are situated in a layer plane in which a heater 55 embedded in the solid electrolyte body is located. For this purpose, heater 55, electrode 50, and electrode lead 55 are pressed onto first insulation layer 12, for example. In a preferred embodiment, heater 55 is produced from the same material as electrode lead 51.